A Novel and Improved Method of Predicting Hand Grip Strength in the Adult Malaysian Population

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Summary

Hand grip strength measurement is a recognized part of hand function assessment. The standard measurement using the Jamar® dynamometer and comparing these results to the recommended normal values suggested by the manufacturers of the Jamar® was questioned as these values were based on Western population. A study comparing a novel method of predicting grip strength using our software was conducted on 25 normal subjects using the LIDO® kinetic workset (Group A and B). These results were then compared against our predictive software (Group A) and the expected values supplied together with the Jamar® Dynamometer (Group B). In another group, 22 normal subjects were tested using the Jamar® (Group C and D) and then matched against the predicted values using their recommended chart (Group C). The last group (Group D) was tested using the Jamar® but the values attained were compared to the results from our software. In group A, the predictability of our predictive method was 100% (both R & L) as compared to (R=64%, L=68%) in group B, (R=27.3%, L=59.1%) in group C and (R=81.8%, L=86.4%) in group D. The differences between the predictability of both methods were statistically significant. The data collected using both the Jamar and the LIDO® kinetic workset correlated well to the data from our software but not to the values suggested by the manufacturers of Jamar®. We conclude that our method of predicting hand grip values are superior to that suggested by the manufacturers of dynamometers. The standard reference for hand grip strength provided by the manufacturers is less accurate in predicting the grip strength of our local population.

Key Words: Hand grip strength, Normative values

Introduction

Reliable and accurate prediction of the normal hand grip strength value is important in determining the results of treatment in patients with hand related problems[1]. The Jamar® dynamometer has been cited in numerous journals at the standard instrument for the measurement of grip strength[2]. It has also been proven to be more accurate than previous dynamometers[3]. Following the manufacturer's protocol of assessment, maximum grip strength measurement (commonly known also as maximal voluntary contraction or MVC), is the most common test administered when using this device. A reference chart (Figure 3) supplied together with the Jamar® dynamometer gives an estimation value of what is expected of grip strength in a normal individual.

Despite its reputation of being reliable and accurate, we came to question this technique of collecting data to be suitable for our local population due to several factors. Firstly, the chart provided with the Jamar® only used age as a predictor to the amount of grip strength generated whereas it is known that several other factors play a role[4]. Secondly, the manufacturer

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based their recommended values collected from Western population which are generally bigger in size than the Asian population. This in turn would imply that within the same age group, the Western population would have higher grip strength. Thirdly, the grip span used in the Jamar was not set at a fixed distance although certain researchers recommend the grip to be at position 3 (which is at 4.7cm). The values attained in the reference chart (diagram) are the result of grip taken from subjects with the grip at the subject's comfortable position. There is no mention of any other methods of positioning the grip handle other than the five positions available on the device. These grip values were not applicable to other grip spans therefore in our sample population which has a small grip span; the values attained may no longer to be accurate[4].

We put our hypothesis to the test by conducting a study using our own predictive software to determine the expected grip strength based on age, hand dominance, sex, weight and height using the LIDO® kinetic workset as a measuring tool [2,5]. This software was created based on 412 normal subjects who were of different sex, age and sizes[2,5]. In comparison, we tested the Jamar's predictability of grip strength based on the manufacturer's recommendations and instructions. In testing the reliability of both devices, we cross examine the values attained from each of these machines and compared them using two references (our predictive software versus the normal grip range provided by the manufacturer's of Jamar). The first one compares the grip strengths against the predicted values from our software and the second is with the values suggested by the manufacturers of the Jamar®. The objectives of our study to prove that the grip strength of our population is lower than that described by Western literature and that our technique of predicting normal grip strength is far superior than conventionally described methods are discussed in the present paper.

Materials and Methods

Forty seven (n=47) normal subjects were recruited for this study. There were two main groups tested: The LIDO group consisted of subjects tested using the LIDO kinetic workset and the JAMAR group consisted of subjects tested using the Jamar dynamometer. Two further sub-groups were created for ease of comparison. The LIDO group consisted of Group A and B, while the JAMAR group consisted of group C and D. Group A had 25 normal subjects tested using the LIDO® kinetic workset with their grip results compared to our predictive software while Group C consist of another 22 normal subjects tested using the Jamar® dynamometer and compared with the table provided by Jamar®. Group B consist of subjects in group A who have had their grip strength measured using the LIDO® kinetic workset but were compared against the suggested values provided by the Jamar®. In contrast, group D is made up of subjects from group C that were tested using the Jamar® but the data collected were compared to the values from our predictive software. A summary is seen in Table I.

All subjects consist of volunteers who were selected randomly by a dedicated technician who also administers the tests and questionnaires. A strict exclusion criteria excluding subjects with hand related problems, previous injuries, neurological disorders and any medical conditions was adhered to. Measurements of the grip strength of all these subjects were done in the manner recommended by the manufacturers of the Jamar. Subjects were tested seating down, shoulders adducted and elbow flexed at 90°. Position 3 is used on the Jamar. Subjects tested using the LIDO kinetic workset followed an almost similar protocol to the Jamar. However, instead of one static value which is attained via a mechanical dial as in the Jamar, the LIDO kinetic workset uses a computer to collect continuous dynamic data with each grip. Subjects grasp the handle of the LIDO kinetic workset for five seconds duration followed by a five second break before the next grip. A complete one minute repetitive cycle of grip and relax is observed. The maximal voluntary contraction (MVC) of the grip produced is then recorded from the data generated. The grip handle on the LIDO is positioned so as the metacarpophalangeal joint is in extension and the proximal and distal inter-phalangeal joints are in 90° flexion. MVC of both the Jamar and the LIDO were measured by looking at the peak of the dial in the Jamar (Figure 4) and the peak of the graph of the first three grips in the LIDO (Figure 2). The highest value is then taken as the value of MVC.

The software we developed was based on hand grip values attained from 412 normal individuals, 212 males and 200 females[2,5]. This data were collected using the LIDO kinetic workset. The grip protocol used was similar to the original protocol. Unlike the Jamar, the grip span for this machine is adjustable to any position with 0.5cm increments. To standardize the grip span for our subjects, the handle of the LIDO is adjusted so that the all our subjects grip the handle with the PIPJ of the index finger flexed at 90° and the MCPJ of the index

finger extended at 0°. The shoulders in these subjects were also adducted and elbows flexed at 90°. Following our statistical analysis, we found that there were statistical correlation between grip strength and age, hand dominance, sex, height and weight [2, 5]. This prompted us to develop a series of hand grip pattern based on our finding. During an evaluation of subjects grip strength, this software will prompt a series of inputs that best describes the individual we are testing (Figure 1). After keying in the necessary information, a grip pattern based on the average values of the individuals that have similar descriptions from our series will emerge. The values attained from the tested individuals are then compared to the values predicted by the software. A value which is within the limits predicted by the software is interpreted as normal (Figure 2).

The normal reference values provided together with the Jamar® were easier to use. Based on the subject's age and sex, a chart incorporating a range of expected MVC strengths are provided. Grip strength (MVC) within the suggested values is considered normal. Subjects are required to grasp the handle of the Jamar® three times with either the average or highest value taken as the MVC. It is worth noting that this chart does not take into consideration other factors such as size and hand dominance as a predictor (Figure 3).

Results

There were 25 subjects tested using the LIDO kinetic workset for group A and B and 22 subjects tested using the JAMAR in group C and D. There were 12 male and 13 female subjects aged between 20 to 57 years (mean age=36.6) in group A and B. In groups C and D there were 9 males and 13 females with the mean age of 33.9 years. There were no significant differences (one-way ANOVA test and independent t-test) in age, height, weight, and the mean grip strength of both hands between the LIDO and Jamar group. All subjects tested in both groups were right handed.

Overall, our predictive software faired better in predicting normal grip strength across the board regardless of the device used to measure the grip strength (Table II). By using our predictive software with the LIDO kinetic workset, we were able to predict the average grip strength accurately in all our subjects. In comparison, the predictive ability of using the Jamar dynamometer with the Jamar chart provided only faired between 32 to 64% sensitivity for determining normal grip strength. In the cross over groups (Results attained from the LIDO kinetic workset compared to Jamar chart and vice versa), The use of our predictive software appeared to be superior with predictability of normal grip strength in 82-86% of subjects as compared to using the Jamar chart which was only between 64-68%.

Using McNemar (non-parametric) test, there were significance difference noted between the predictability of using the Jamar chart and our predictive software (p value < 0.01) in both groups comparing the same hand. This however, was not seen by comparing the left hand in the Jamar group (Table III). In this group, the ability of grip strength prediction between using our predictive software and the Jamar chart was not significantly different (86% vs. 59%). Between the LIDO group and the Jamar group, using a non-parametric Kendall W test, there were significant differences noted in the ability to predict normality in the grip strength of both hands using either the Jamar chart or our predictive software (p value < 0.001). Notably, in each of our Chi Square test (testing the grip strength of each hand, and comparing results attained from both instruments), there were significant differences between the results attained by using our predictive software (p value<0.001) but not by using the Jamar chart. It is noted that in the groups using the Jamar chart, the percentage of predicting normality were also low. In reviewing the results of predictability (in Table II and III), we can deduce that by using our predictive software, the ability of predicting positive tests were high enough to differentiate normal from abnormal grip strength. However, by using the Jamar chart, the positive results attained cannot be differentiated between the normal and abnormal results, resulting in high number of false negative results being reported.

Discussion

The knowledge of normative values is of paramount importance as they serve as the reference point to distinguish between normality and abnormality. Together with the proper, valid, accurate and reliable evaluation of hand grip strength measurement, the effectiveness of any surgical and non-surgical interventions of hand problems can be monitored and compared. In addition, normative data are needed to interpret evaluation data; to set realistic treatment goals; and to assess a patient's ability to return to employment.

Table I: Groups A and B were the same test subjects tested only once using the LIDO. Groups C and D were from the same test subjects but were different from groups A and B. Because two different predictive methods are being tested while the device remains the same, subjects needs to be derived from the same population sampling.

Group	Description	No. of subjects
A	Subjects were tested using the LIDO and the data attained was compared to the values suggested by our predictive software M	(n=25) ale=12 Female 13
B	Subjects were tested using the LIDO and the data attained was compared to the values suggested by the values suggested by the manufacturers of the Jamar	(n=25) Male=12 Female 13
C	Subjects were tested using the Jamar and the data attained was compared to the values suggested by the values suggested by the manufacturers of the Jamar	(n=22) Male=9 Female 13
D	Subjects were tested using the Jamar and the data attained was compared to the values suggested by our predictive software M	(n=22) ale=9 Female 13

Table II: The results presented in this table cross-tabulate the results attained by examining normal subjects using the LIDO kinetic workset of the Jamar dynamometer. These results were then compared to determine normality using using our predictive software or the Jamar chart as reference. The values within the boxes represent the percentage of cases noted to be predictive in respect to the Jamar reference charts/ predictive software used.

	LIDO group (n=25)		Jamar group (n=22)	
	A (using predictive software)	B (Using the chart provided by Jamar)	C (Using the chart provided by Jamar)	D (using predictive software)
R hand	100*	64*	27.3*	81.8*
L hand	100*	68*	59.1*	86.4*

* represent the values in percentage of the samples that were tested and found to be within the predictive values.

Table III: The table shows the results of McNemar (non-parametric) test to compare between the Jamar chart and our predictive software in each group and each hand.

	LIDO group		JAMAR group	
Comparison between Jamar chart & our predictive software (McNemar test)	Left hand	Right hand	Left hand	Right hand
P value	**0.008**	**0.004**	**0.146**	**0.008**

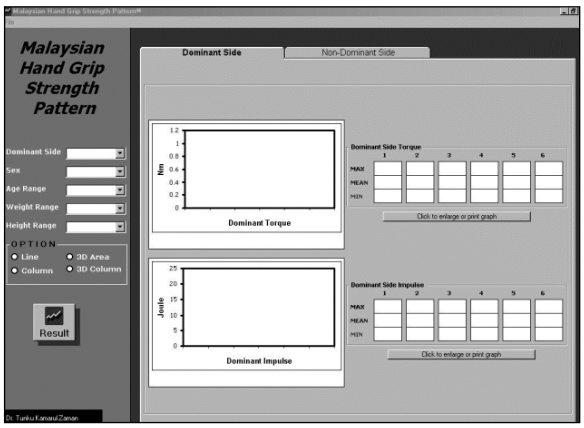

Fig. 1: The front page of the predictive software used for this study.

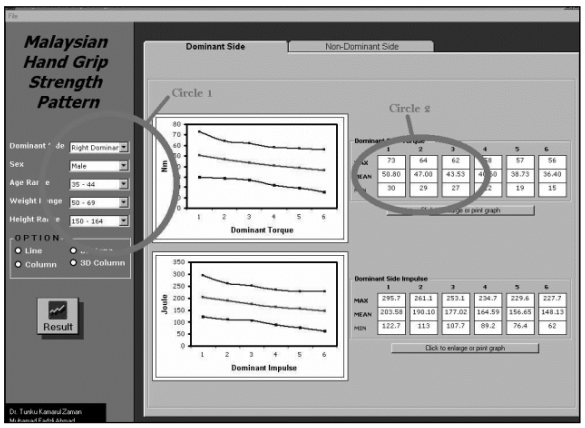

Fig. 2: The values (parameters) of the subjects are selected as seen in circle 1, following that the expected results are then predicted as graphs and tables. Only the values of the first 3 and the average are taken (as in circle 2). This is to standardize the method used to attain results as suggested by the chart provided by the manufacturers of the Jamar dynamometer. Note that although not used in this study, grip patterns can also be attained from this software.

Table II: Performance of All Subjects an Grip Strength (pounds)

		Men					Women				
	Hand	Mean	SID	SE	Low	mm	Mean	SID	SE	Low	High
20-24	R	121.0	20.6	3.8	91	167	70.4	14.5	2.8	46	95
	L	104.5	21.8	4.0	71	150	61.0	13.1	2.6	33	88
25-29	R	120.8	23.0	4.4	78	158	74.5	13.9	2.7	48	97
	L	110.5	16.2	3.1	77	139	63.5	12.2	2.4	48	97
30-34	R	121.8	22.4	4.3	70	170	78.7	19.2	3.8	46	137
	L	110.4	21.7	4.2	64	145	68.0	17.7	3.5	36	115
35-39	R	119.7	24.0	4.8	76	176	74.1	10.8	2.2	50	99
	L	112.9	21.7	4.4	73	157	66.3	11.7	2.3	49	91
40-44	R	116.8	20.7	4.1	84	165	70.4	13.5	2.4	38	103
	L	112.8	18.7	3.7	73	157	62.3	13.8	2.5	35	94
45-49	R	109.9	23.0	4.3	65	155	62.2	15.1	3.0	39	100
	L	100.8	22.8	4.3	58	160	56.0	12.7	2.5	37	83
50-54	R	113.6	18.1	3.6	79	151	65.8	11.6	2.3	38	87
	L	101.9	17.0	3.4	70	143	57.3	10.7	2.1	35	76
55-59	R	101.1	26.7	5.8	59	154	57.3	12.5	2.5	33	86
	L	83.2	23.4	5.1	43	128	47.3	11.9	2.4	31	76
60-64	R	89.7	20.4	4.2	51	137	55.1	10.1	2.0	37	77
	L	76.8	20.3	4.1	27	116	45.7	10.1	2.0	29	66
65-69	R	91.1	20.6	4.0	56	131	49.6	9.7	1.8	35	74
	L	76.8	19.8	3.8	43	117	41.0	8.2	1.5	29	63
70-74	R	75.3	21.5	4.2	32	108	49.6	11.7	2.2	33	78
	L	64.8	18.1	3.7	32	93	41.5	10.2	1.9	23	67
75+	R	65.7	21.0	4.2	40	135	42.6	11.0	2.2	25	65
	L	55.0	17.0	3.4	31	119	37.6	8.9	1.7	24	61
All Subjects	R	104.3	28.3	1.6	32	176	62.8	17.0	0.96	25	137
	L	93.1	27.6	1.6	27	160	53.9	15.7	0.88	23	115

Fig. 3: The result taken from the published article by Mathiowetz *et al* (1) which is similar to the results presented in the chart provided by the Jamar dynamometer. The chart above was used as reference in groups B and C.

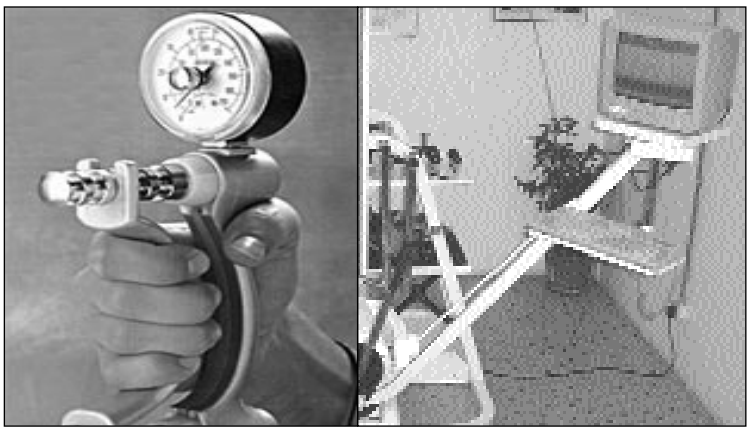

Fig. 4: The picture above left is an example of the Jamar used in this study. The picture above right is the LIDO kinetic workset was used in creating our predictive values and subject testing.

The most common norms for grip and pinch strength used in therapy clinics were compiled by Mathiowetz *et al* with the first published results seen in 1985[1]. The use of the Jamar dynamometer was fully described and was made as the reference chart of most hand clinics in Malaysia even today. Little did most physicians and therapists realize that these data were created from American (western) population which may not represent the hand grip strength of our local population. Furthermore these values did not take into consideration of the influence of hand dominance as a predictor[1]. In a similar study by Kamarul *et al*[5] there have been statistical significances noted in the grip strength of different hand dominance and should be considered as a valid predictor. Our study using randomized control groups comparing the different equipments and different predicting methods have clearly demonstrated that the use of local data and better predicting charts were much superior to conventional means of predicting hand grip strength. This also proves that the use of sex and age as predictors alone is not sufficient in determining the normal grip strength. In a related research conducted by Kamarul *et al*, the determination of grip strength was more predictive if hand dominance, occupation, height and weight were also considered (r square value of 0.11-0.29 for height and weight as compared 0.2 for sex)[2]. The predictability of grip strength using sex, height, weight, and age and hand dominance was also noted by Hanten *et al*[4].

Other results which are largely used are the likes of Kellor's group[7] which sampled 250 individuals in three large age groups. Regression analysis was performed to predict the amount of right hand (RH) or left hand (LH) strength an individual of a given sex and particular age would demonstrate. Since few left-handed subjects were tested, their scores were combined with those of right-handed subjects. No standardized positioning or instructions were followed. Test-retest and inter-rater reliability data were not reported. The Osco meter used in their study is no longer commercially available and them is some question whether data from use of the newer dynamometers can be validly compared to their norms.

The Jamar was thought to be the best equipment for gathering hand grip strength data due to it robust and simple design. More importantly it was claimed to be an accurate and reliable device for hand grip strength measurements[9,10]. However, in this study, it is evident that data source and data interpretation plays as much a crucial role in determining the accuracy of predicting normal values as a valid and accurate measuring device. It is therefore important that local data representing the normal value of a study population or patients be made available to health workers. This move will greatly reduce the inaccuracies of data presentation and misinterpretations.

Using data from a previous study, we examined hand grip strength data obtained from our local population and compared them with values obtained from Western population [2,5]. Our method of grip strength had advantages over the simple method of grip strength prediction described by the manufacturers of the Jamar;

which only employs sex, age and hand side as predictive factors. In our predictive method, in addition to these parameters, we also used hand dominance, height and weight as confounding factors. As a result, the values obtained for hand grip prediction are more predictive and specific to the population that is being tested.

Other authors have also described the use of the normal side as a predictor of the expected grip strength of the abnormal side. In general, the right hand is approximately 10% stronger than the left. By using this rule, one can predict the normal strength of a grip by comparing to the other. However, this method of prediction has its limitations. Firstly, in a study conducted earlier we found that although the right hand is approximately 10% stronger than the left (12.1% in male and 11.0% in female) there is a variance of between 9.1 to 9.6% in different individuals [6]. Secondly, it is only predictable if the individual has a normal side to compare to and cannot be used in patients with injuries involving both hands. Furthermore it has been reported that measured grip and pinch strengths in non-manual, light manual and heavy manual workers using a Jamar dynamometer and a pinch measuring device had significant and variable side to side difference. Heavy manual workers had the strongest grips with the least difference between sides. Office workers had the weakest grips and the greatest difference between sides. Light manual workers were between these two groups. Consequently, the occupation of the patient must be taken into account when using grip and pinch strength measurements to assess the need for rehabilitation and in medico-legal reports[11]. The issue of whether hand dominance is of influence to grip strength remains a contentious one. While some authors do not feel that there are differences between left and right hand dominant group[1,3,11] others have proved otherwise[2,4,5,7,12]. It has been found that in left hand dominant individuals, the dominant hand (left hand) had the same grip strength as compared to the right in 50% of this population. Other studies showed that the average grip strength of the dominant hand in left handed subjects were higher[2]. Thus, this rule predicting one hand by comparing to the other cannot be justified[12]. It is interesting to note that in one paper, the authors attempted to create an equation to predict hand grip strength. However, even these authors found that the simple and full model equations for handgrip strength were less predictive in adults[13].

Some limitations have been noted in the study conducted in the present report. Due to time and financial constraints, we were unable to recruit more subjects for this study comprising of subjects with different test parameters. This would allow us to study the significant impact our prediction method has on subjects of different occupations, race etc. To prevent biased sample in favor of higher hand strength scores, there was an attempt to avoid a competitive atmosphere at the testing sites. However, we were not able to validate this is in our study. Furthermore, our research method only assumed that the subjects recruited for our study were of normal population and was not able to eliminate some errors that may result if any abnormality occurred among our subjects that may not have been detected during the screening process. This was of course, despite careful screening of subjects. It would also be important that future studies should include testing for negative controls as it would help to determine the number of false positive (false normal) results that may have generated from using both methods.

Conclusion

Normative data of hand grip strength is important to determine abnormalities in hand grip function. Improper data will result in data misinterpretation thus resulting in high numbers of misreporting. Data provided by the manufacturers of the JAMAR, the method of data collection and hand grip prediction method is less reliable when applied to our local population. Having local data as a reference rather than western data, grip strength prediction would have better accuracy if other factors such are weight, height, and hand dominance were also considered.

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